DOCUMENT RESUME

ED 194 482 SP 016 956

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TITLE Trends and Research Questions in Research on Learning and Schooling.
PUB DATE Jan 80
NOTE 24p.: Prepared for Subcommittee on Elementary, Secondary, and Vocational Education "Needs of Elementary and Secondary Education in the 1980's: A Compendium of Policy Papers." For entire document (microfiche only), see ED 185 660. For individual documents (microfiche and paper copy), see SP 016 934.

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Achievement Tests: *Classroom Research: Cognitive Processes: Elementary Secondary Education: Grade Prediction: *Intelligence: Mathematics Education: Mathematics Instruction: *Reading Research: Reading Skills: *Research

ABSTRACT

This paper concentrates on cognitive psychological research on school subjects using as illustration work in reading, mathematics, and aptitude for learning. In general, the work in reading research can be characterized in terms of three themes: (1) comprehension as the construction of knowledge: (2) the structure of text: and (3) reading as the acquisition of a skill. In mathematics, research is largely centered around the polarity and tension between emphasis on the learning of procedural rules for solving problems on the one hand, and emphasis on "meaningful" instruction and mathematical "understanding" on the other. Researchers on intelligence and aptitude are unhappy with the state of the art for a number of reasons. Most important are: (1) Given our present techniques, theoretical understanding of the abilities measured, and the usual forms of testing, we have reached a plateau of efficiency: (2) The tests provide minimal information--useful for selective decisions about entrance into a program, but not diagnostic enough to affect the conduct of instruction: and (3) Current test theory and technique have not made contact with new developments in the psychology of learning and cognition. (Author/RJG)

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TRENDS AND RESEARCH QUESTIONS IN RESEARCH ON LEARNING AND SCHOOLING[1]

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The boundaries between basic and applied research are becoming increasingly blurred for many psychologists now studying the educational process. Examination of recent work on the nature and development of human knowledge and intellectual skills makes it apparent that this research is both fundamental in character and, at the same time, directed toward practical understanding. An interactive network between behavioral science and education appears to be developing in a strong way. Examples of such research are presented in this paper to illustrate this point. This discussion should indicate that in the 1980's, research relevant to education will involve both strong interactions with an advancing science of human cognition and increasingly sophisticated analyses of schooling.

A major reason for this surge of activity is the capability of current psychological theory for investigating complex thought processes, coupled with the conviction that the interaction between basic and applied research can be mutually beneficial for society and for science. The trend is apparent in many different fields of psychology, including the study of learning, performance, development, the processes of schooling, and methodologies of data analysis. On the side of education, practitioners and their constituencies are demanding useful information

[1] In early drafts of this paper, I profited from the inputs of my colleagues James Greeno. Alan Lesgold, William Cooley, Margaret Wang, and Kathleen Corsale. Changes in the final draft were suggested by Mary Beth Curtis. None of these individuals are responsible for my interpretations.

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for policy analysis and decision making. Questions are being raised about the rationale and utility of curriculum materials, the assessment of achievement, and the organization of instruction. Classroom processes are being analyzed in detail including the effects of the actual amount of time allotted to various subject matters, and the planned and unplanned events that result when new curricula are implemented. Analysis is being undertaken of how education is monitored through placement tests and competence examinations. New methodologies oriented toward describing causal relationships in the educational process offer the possibility for improved understanding of the conduct of schooling.

In this paper, I concentrate on cognitive psychological research on school subjects using as illustration work in reading, mathematics, and aptitude for learning. For reasons of time and space, I, unfortunately, slight the growing amount of research by educational researchers and social scientists on evaluation and teaching practices in schools and classrooms. In this latter respect, I only allude to two areas of general interest--achievement measurement and school process studies--to indicate the possibility of articulation between global studies of school systems and specific studies of human cognition and performance.

Reading and the Comprehension of Text

Reading processes have been carefully investigated in both laboratory and classroom settings (e.g., Frederiksen, in press; LaBerge & Samuels, 1974; Perfetti & Lesgold, 1977, in press; Resnick & Weaver, in press). At the present time, a good deal is known about the psychological processes involved when individuals must translate printed symbols into spoken language. Children come into the classroom with skills of a spoken language, and an initial activity in learning to read involves learning the new visual mode

of receiving language--that is, the process of decoding from print to sound. Enough is known about the psychological aspects of this process so that many researchers are now moving into strong development work, analyzing teaching practices and instructional materials in terms of what is known about the decoding process (Beck & McCaslin, 1978).

It is also true, however, that learning to read is dependent on getting meaning out of what is read, but the ability to use and learn from language has been less systematically studied than decoding. At the present time, the long-standing debate about the relative importance of decoding instruction and experience with language appears to be decreasing. This is occurring in recognition of the fact that competition between the two is an essential component of learning to read. Learning to decode requires a controlled vocabulary, and developing language experience requires a richer language base which matches the child's actual life experiences and understanding. This conflict between simplification and richness is now seen as a normal state of affairs around which instruction has to be designed in a systematically effective way. With this understanding, the practical problem becomes one of technical development. Teaching practices and materials that appear to solve the problem need to be systematically analyzed and studied both to assess their claims and to learn from their art. Thus, beginning reading is now largely (certainly not entirely) a development problem that requires work that is difficult, but that is not submerged because of lack of knowledge.

After the primary grades, as expectations for language use become more sophisticated, there is no clear evidence supporting the superiority of prior use of either decoding or language approaches to instruction. There is little, if any, evidence that too much emphasis on decoding depresses

eventual comprehension. Neither is there evidence that once decoding skills are learned, other reading problems are alleviated. However, there are data to suggest that decoding and comprehension are interdependent. If too much effort must be invested in decoding, the speed and ease of comprehension is depressed, and at the upper levels of elementary school and high school, poor comprehenders may display decoding deficiencies that interfere with comprehension (Resnick & Weaver, in press). One implication of this for the future is that the degree of efficiency that comprehension demands of decoding processes must be assessed. A conceivable outcome of this work is that new kinds of diagnostic tests will be developed--tests that assess the speed and efficiency of decoding and the extent to which decoding skills reach a level where comprehension can readily occur (Lesgold, Resnick, & Beck, 1978; Resnick & Beck, 1976).

In contrast to the initial steps in reading, a lack of knowledge is apparent with respect to the more advanced stages of comprehending, such as using text in order to learn from it, and analyzing ideas (Sticht, Beck, Hauke, Kleiman, & James, 1974). This kind of skill has not been as carefully studied as the more "mechanical" aspects of the stages of early reading. But interesting research is being pursued on these upper levels of comprehension, and there is direct concern with the use of written language as a vehicle of thought. In general, the work going on can be characterized in terms of three present research themes that shall be briefly described: (a) comprehension as the construction of knowledge, (b) the structure of text, and (c) reading as the acquisition of a skill.

Let us look first at <u>comprehension as the construction of knowledge</u>. This first theme reflects a change from viewing comprehension as a passive process to viewing it as an active one. In this latter view, comprehension

involves using what one already knows to remember and get new information from what is being read (Anderson, 1976; Bartlett, 1932; Bransford & Franks, 1971; Lenat, 1976; Minsky, 1975; Spilich, Vesonder, Chiesi, & Voss, 1979). One implication of this concept for future efforts on the teaching of reading is that careful attention needs to be paid to both (a) the relationship between an individual's familiarity with the knowledge domain in a reading passage, and (b) the influence of this knowledge on developing skills that enable a text to be read and understood. Disparities between the content of elementary reading texts and the knowledge that a child brings to school result from a lack of attention to this relationship.

A second theme is represented by work on the structure of text (Kintsch, 1977; Mandler & Johnson, 1977; Rumelhart, 1975; van Dijk, 1977). Research of this kind is beginning to emphasize that there are many patterns of text, just as there are many kinds of sentences. There are specifiable structures for narrative tales, scientific texts, rational arguments, and reporting of events. The implication of this for the future is that reading curricula can more systematically include the teaching of various forms of text.

There are two potential contributions to reading instruction that can follow from the above research themes--comprehension as construction of knowledge and the structure of text. First, as we attend to the relationship between a child's background knowledge and the learning of comprehension skills, we will understand more about the assumed knowledge and forms for communication that come from different experiences. As a result, we should be able to teach to these differences with more sensitivity. Secondly, this new research can provide a basis for determining what kinds of skills are important in reading different forms of text, such as newspapers, tax

forms, history books, instructional manuals, etc. These distinctions can be explicitly taught to individuals so that they can adjust and tune particular reading skills accordingly.

A third theme concerns the conception of reading as the long-term acquisition of a skill. As a result of current work, an old area in psychology concerned with skill acquisition is being reemphasized. A central question involved is how expertise develops, and what is the nature of expert skill. In the past, educational researchers have emphasized the importance of readiness skills and prerequisites for learning; however, they have devoted less attention to understanding expert performance learned over the long term. It appears that we have attended too much to the short run in learning and are now coming to appreciate more fully how much training and practice a major skill requires before high levels of competence are attained (Chi & Glaser, in press; Larkin, 1978; Simon & Simon, 1978). The development of skill toward progressively higher levels of expertise often takes longer than we think, and investigation of this problem relates directly to the use of time in a school day and to practice out of school. Attention to the aspects of long-term skill development will probably contribute to cracking the problem of what happens to reading achievement after the second or third grade. Studies show that the effects of better primary curricula disappear for many children in the later years of elementary schooling. Detailed and expensive studies of the same children over a period of time will be required to find out why some fall behind and what characteristics of early reading performance are predictive of future problems.

Mathematical Skill and Understanding

Now let us take a look at what is happening in the investigation of mathematical skill and understanding. A skill versus understanding debate

like that in the field of reading has also been present in mathematics instruction since early in this century (Brownell, 1928). The debate is characterized by polarity and tension between emphasis on the learning of procedural rules for solving problems on the one hand, and emphasis on "meaningful" instruction and mathematical "understanding" on the other. In recent years, the work on computational rules has been influenced by research on computer instructional systems that seek to provide maximally effective drill and practice programs. The work on meaningful instruction derives in large part from the influence of Piaget and from the Woods Hole (Bruner, 1960) and Cambridge (Goals for School Mathematics, 1963) conferences that led to recommendations for teaching the concepts of mathematics as a foundation of understanding. These influences contributed to the curriculum reform of the 1960's and the label "new math." Today, the skill versus understanding debate appears to be active again as evidenced by the concern over the effects of the new math curricula (which may, in reality, be a concern for how well these curricula have been implemented), and the "back-to-basics" movement (although this movement has many different meanings). The interrelationship between the use of rules and understanding is also an active research area in the study of human cognition.

A report by the National Advisory Committee on Mathematical Education (1975) addresses this issue in the context of needed research and development for K through 12 school mathematics. A major policy recommendation of the committee is called "anti-dichotomy." This recommendation, in summary, states that in the introduction and support of mathematics programs, neither those responsible nor the general public ought to allow themselves to be manipulated into "false choices between the old and the new in mathematics, skills and concepts, structure and problem solving" (p. 136). The committee

suggests that the core of every mathematics program should judiciously combine both elements of each pair, with the appropriate balance determined by the nature and goals of a program. Deploring the polarization of issues as uncommunicative and unproductive, the report proposes limiting the term "new math" to the developments during the period 1955 to 1975. Implicit in this recommendation is a recognition of the need for research on the nature of mathematics as a human cognitive performance. This requirement articulates well with recent research developments on the nature of mathematical knowledge and problem solving, and on how skill and understanding in mathematics are acquired. Investigations are being carried out in the fields of cognitive psychology, computer simulation, and artificial intelligence. Scientists in these various fields now see the field of mathematics, because of its more structured and transparent content relative to other subject-matter areas, as a domain in which their work will be able to make strong contributions to instruction (Anderson, 1976; Greeno, 1978; Norman & Rumelhart, 1975; Schank & Abelson, 1977).

Computation and problem-solving skills are being investigated with the new concepts and methods that are available for analyzing in detail the nature of cognitive processes (Brown & Burton, 1978; Gelman & Gallistel, 1978; Newell & Simon, 1972). With respect to the skills of computation, the general belief that "practice makes perfect" is being carefully examined. This belief is true only insofar as practice is necessary, but not sufficient, for developing skills. Children can practice errors and misconceptions, or practice in ways that do not produce advances in skillful organized performance. Many errors that occur do so not because of a simple lack of knowledge or inattention on the part of the child, but rather because of sensible misconceptions or use of incorrect rules. With this in mind, research effort

is currently being devoted to the study and development of sophisticated diagnostic materials--materials that do more than test for correct or incorrect answers and assist in finding "bugs" and misconceptions in children's knowledge. Work of this kind will help teachers to become aware of systematic bases for errors that need to be monitored when a learner is reaching toward the next stage of learning (Brown & Burton, 1978).

In the area of problem solving, certain results indicate that a student's proficiency involves sophisticated cognitive strategies that should be recognized and explicitly taught. For example, detailed analyses of problem solving in geometry have indicated that three kinds of knowledge are involved: (a) knowledge of the similarities and differences between geometric objects, such as points, line segments, angles, and so forth; (b) knowledge that is used to make inferences and to prove theorems, e.g., "corresponding angles are congruent," or "the sum of the angles of a triangle is 180 degrees"; and (c) strategic knowledge that is used to set goals, form plans and, in general, to organize activity on the problem (Greeno, 1978).

In the context of classroom instruction, in teaching and in textbooks, the first two kinds of knowledge just mentioned are explicitly taught, but the third is not. The first kind of knowledge, required for recognizing the pattern of geometric objects, is a skill that is usually instructed with diagrams and exercises to give practice in identifying the visual features and relationships that students need to perceive. The second kind of knowledge required in making inferences during problem solving is also communicated through explicit instruction in the classroom and in textbooks. However, the third kind of knowledge, strategies used in setting goals and formulating plans, is not explicitly a part of instruction

in the content of geometry. This strategic knowledge is generally relegated to the student's general ability (or intelligence) to apply the knowledge that is actually taught. An alternate view, however, is that such strategic problem solving also should be explicitly taught. The strategic knowledge needed for problem solving can be learned and should be considered as a part of knowing that skill. If this is indeed the case, then a problem for instructional research is to investigate ways in which these strategies can be taught so that they are fostered in students who are not able to readily induce them. Research of this kind is now seen as an important aspect of mathematics instruction and the study of problem solving. A related point is that excellent teachers, by virtue of the way in which they select and organize examples and problems in their teaching, have implicit systematic ways of teaching strategic knowledge. This expertise should be studied in detail so that it can be specified and generally transmitted to others.

In the context of the "anti-dichotomy" recommendation and present research efforts, it should be pointed out that the old distinction between procedural rules and understanding is undergoing careful study. Simply stating that this is a false dichotomy will not make it so. What is required is understanding the relationships between these two forms of knowledge. At the present time, work in cognitive psychology and artificial intelligence is developing new insights into this problem. If these investigations are successful, then it should be possible to override the debate on the rule-versus-understanding issue. The ways in which the two domains of knowledge reinforce and facilitate each other will be made more explicit so that relevant understanding and the use of rules in mathematical procedures can be more properly balanced in school programs.

Aptitude and Intelligence

Past research and development on aptitude and intelligence have led to technological advances which have been designed to serve the established patterns of schooling. However, at the present time, this technology may no longer be appropriate for the new values and new conceptions of the educational process. This realization has resulted in stopgap measures such as the suspension of standardized intelligence testing, the attempt at quick design of diagnostic assessment instruments, and changes in selection and entrance procedures. Unfortunately, many of these immediate measures can be successful if and only if there are accompanying changes in the patterns of schooling. For example, it is difficult to see any significant accomplishments resulting from relaxing the entrance requirements to a college or mainstreaming "learning disabled" children to a classroom without making the instructional process more flexible so that the time and tactics of instruction can be varied for different individuals. Research and analysis is proceeding along these lines at the level of school management and teaching process (e.g., Brophy & Everetson, 1976; Cross, 1975; Doyle, 1977; Gage, 1978; Glaser, 1977).

Researchers on intelligence and aptitude are uncomfortable with the state of the art for a number of reasons. In general, it is clear that the intelligence tests and measures of verbal and quantitative aptitude used in schools measure the kind of intellectual performance that can be most accurately called "general scholastic ability." We know that the abilities that are tested are related to success in school, but we also know that this kind of knowledge will not provide the understanding that is required to encourage, enhance, or to remediate these abilities for learning. More specifically, current doubts and dissatisfaction with

tests that measure abilities for learning appear to stem from three main sources: (a) Given our present techniques and theoretical understanding of the abilities measured, and given the usual forms of testing, we have reached a plateau of efficiency, such that efforts to improve current tests have run into diminishing returns. (b) The tests for the most part provide minimal information--essentially information useful for go/no go selective decisions about entrance into a program, but not diagnostic enough to affect the conduct of instruction. To be considered adequate, diagnostic measures should assess differences in cognitive abilities and acquired knowledge that indicate how schools can adapt their environments for learning to diverse individual needs. (c) Finally, from a scientific point of view, there is the recognition that current test theory and technique have not made contact with new developments in the psychology of learning and cognition. Modern psychological theory may be able to bring us closer to understanding what underlies the abilities for learning that contribute to success in school.

With the above needs in mind, programs of research have been designed to bring the concepts and methods of cognitive psychology to bear on the analysis of the abilities that aptitude and intelligence tests are measuring (Carroll, 1976; Estes, 1974; Hunt, Frost, & Lunneborg, 1973; Pellegrino & Glaser, 1979, in press; Snow, in press; Sternberg, 1977). In the initial phases of research of this kind, the items from the tests become the object of theoretical and experimental analysis. The immediate objectives are to analyze the items in terms of the knowledge and skills that are required to answer them correctly, and then to use this analysis for understanding what underlies incorrect answers. The subsequent task is to conduct instructional experiments where the objective is not to train individuals

to score higher on these tests, but to develop practical understanding of how the cognitive functions that underlie skill in learning, and that contribute to successful performance in school, can be directly or indirectly influenced.

In general, the cognitive analysis of aptitude and intelligence previews the kind of research effort that must be undertaken before new measures of intelligence, aptitude, and human performance "will move many psychometric predictions from static statements about the probability of success to dynamic statements about what can be done to increase the likelihood of success" (Hunt, et al., 1973, p. 118). Hopefully, new concepts of aptitude and intelligence that emphasize the cognitive processes of human performance will foster the development of educational possibilities that increase individual accomplishments.

Achievement Measurement

Questions about achievement testing are arising from all sides. How is the information obtained from achievement tests used in schools to guide instruction and to make administrative decisions? How is the measurement of achievement related to demands for standards (Glass, 1978)? What do grade-level scores tell us about children's performance that can be used to influence teaching practices? What does it mean, in terms of demonstrated competence, when a child progresses from a grade-level score of 6 to 6 years, 8 months; what is the practical significance of this difference? These and other questions are being responded to in a number of ways, including the development of programs of assessment and competency-based testing. Hopefully, this development will be accompanied by thoughtful and reasonably long-term study of the effective design and implementation of such programs. Their impact on changes in instruction and school

management and the social consequences of these testing programs certainly need to be studied.

A second response to the demands for the effective assessment of achievement has been increased concern with the theory and technology of achievement measurement. What psychologists know best is the technology of designing tests for the prediction of success in school, and this technology has led to the construction of tests used for selective purposes. In contrast, the theory of achievement testing and techniques for the diagnosis of an individual's attained knowledge and learning resulting from instruction are less well developed (Hambleton, Swaminathan, Algina, & Coulson, 1978; Popham, 1978). Confusion in this area has arisen to a large extent because of the attempt to use concepts and techniques developed for aptitude and intelligence testing for the measurement of the outcomes of learning. It is one task to design a test for the purposes of predicting school performance, but a different task to develop adequate measures of school performance itself. In the future, it is to be anticipated that research on the development of adequate performance measures and on the stages of subject-matter knowledge, in areas such as text comprehension and mathematical skill, will contribute to new practices for assessing competence. These practices should result in information that is indicative of the details of attained individual abilities, and thereby effectively integrate the information obtained from tests with the guidance of learning.

School Processes

Related to the guidance of learning is also the growing body of research which concentrates on classroom practices and macro-instructional

processes.[2] This research is becoming increasingly sophisticated with respect to the investigation of classroom processes through detailed analyses of the conditions under which learning takes place in school contexts. Past studies designed to evaluate curriculum innovations attempted to describe school learning by relating the nature of student input to the quality of student output, and only very generally described the processes intervening between the two. In curriculum implementation studies, detailed information was rarely obtained about differences between effective and less effective classroom processes in terms of some model of classroom instruction. Models are now being developed that attempt to explain the variation obtained in achievement measures in terms of the initial ability of the student, classroom process variables, and the interaction between the two. This work is being facilitated by the use of new statistical and methodological techniques developed for observational research and field experimentation. In the past, most methodological development in experimental design was devoted to procedures to be used in controlled laboratory situations. Attention is now being paid to the development of techniques that apply more directly to school variables and the allocation of educational effort (Cooley, 1978).

Work along these lines involves systematic definition of the details of important dimensions of classroom instruction (Bloom, 1976; Brophy & Everetson, 1976; Brophy & Good, 1974; Carroll, 1963; Cooley, 1978; Cooley & Leinhardt, 1975; Koehler, 1978; Rosenshine, 1978; Stallings, 1975; Suppes, Macken, & Zanotti, 1978; Wiley & Harnischfeger, 1974). What is being

[2]The term "macro" is used here to contrast the level of variables studied in this area with the micro-processes of cognition discussed earlier. Both levels of analysis and their interrelationships need to be rigorously studied for an effective understanding of learning and schooling.

studied no longer are inadequately defined and implemented curricula, but rather, the components of operating programs that actually contribute to or detract from classroom effectiveness. These analyses provide information for practical implementation decisions and also contribute knowledge to potential theories of classroom teaching practices. The development to be anticipated is a growing macro-theory of teaching and instruction: "macro" in the sense that it is concerned with the large practical variables dealt with in schools such as the allocation and efficient use of time, the structure of classroom management, the nature of teacher feedback and reinforcement to the student, the organizational pattern of teacher-student interaction, the relationship between what is taught and what is tested, the degree of classroom flexibility required for adapting to learner background, and the details of curriculum materials as these relate to teaching practice and student achievement. Such variables need to be part of a theory of teaching in the same way that the large variables of economic theory are applied to economic change. As theory at this level develops, it will be undergirded by the more micro-studies of human thinking, problem solving, and the learning of school subjects. It is possible that, in the future, the two levels, macro- and micro-investigations, will become increasingly articulated in studies of classroom learning and the development of human cognition.

Concluding Remarks

The trends and research questions briefly covered in this paper reflect the conviction that education no longer can be content to be a major profession in our society whose practices are little influenced by developments in science and technology. This state of affairs is no longer tolerable under the press of the current problems of education and is no

longer possible in the light of the recent developments in the behavioral and social sciences. In the past 15 years, these sciences have moved strongly into the study of skilled and complex human performance and into the analysis of institutional processes relevant to the educational enterprise. Reading and mathematics ability, learning and thinking, and general problem-solving skills are being studied with powerful new techniques. Increased understanding is being obtained about the influence of conditions of life and schooling upon the development of essential literacy and intellectual competence in children and adults. Long-term studies of the organizational patterns of education and the processes of schooling are now being carried out in the context of pressures for the assessment of achievement and for the evaluation of institutional effectiveness.

Two sources of information--increasing understanding of human learning and performance, and analysis of the outcomes of schooling and the effective use of educational resources--will undoubtedly influence policies and patterns of education. Organizational inertia will be overcome by the increased amount of information available to parents, students, and teachers--particularly with respect to the capability of the educational institutions to adapt to the diversity of individuals they serve and to provide both quality and equality in education. In the 1980's, it seems likely that the educational profession will begin to receive the scientific support that should undergird a strong profession.

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